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## THE DEVELOPMENT OF ILLUMINATION<sup>1</sup>

By WALTER HOUGH

Before the period of artificial illumination there were many manifestations of light in nature coming to the aid of the denizens of the earth during the hours of darkness. Of these were the so-called luciform appearances, including the aurora borealis and australis, which enliven the long nights at the polar zones; the magellan clouds of the southern hemisphere; the zodiacal light whose cause was long a subject of speculation; and the diffused light of the milky way, known to the Chinese as the "River of the Sky."

The light from the stars and planets is not inconsiderable. Under the clear night sky of the Arizona deserts the atmosphere seems charged with star mist; eminences miles away may be outlined, the dial of a watch may be read, and a trail followed with little difficulty. These are the conditions under which night journeys are made to avoid the burning sun. The planet Venus, at inferior conjunction especially, sheds light sufficient for the traveler over open country.

There are at times nights of remarkable luminescence. Clouds become phosphorescent, and often under certain states of electric stress, during high winds, glimmer with a faint light not amounting to a discharge of the electric fluid. Frequently successive flashes of "heat lightning" aid the traveler in finding his way. It is possible, also, that the soil over certain regions may become phosphorescent under the light of the sun and retain the property during the night, as certain gems are phosphorescent

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<sup>1</sup> Read at the Congrès International d'Anthropologie et d'Archéologie Préhistoriques, XII Session, Paris, August, 1900.

after being submitted to sunlight. Snow has this property. Gaseous emanations of a phosphorescent character are occasionally abundant enough to produce temporary illumination.

Next to the sun in value to man as a light producer is the moon. Though intermittent in the power and duration of its light, the moon has proven a valuable auxiliary on the night side of man's life, and its period has given a measurement of aggregates of time.

In torrid climates, and at hot seasons of the year, work is often carried on by moonlight in order to escape the heat of the day. While moonlight is 450,000 times less bright than daylight, under certain favorable conditions the light seems intense and ample for many purposes.

The well-known phosphorescence of lichens has been found to give considerable light during warm, moist nights in the summer. Certain flowers are phosphorescent, or emit flashes of light, as the tuberose and moonflower. In the vegetable world there are numerous sources of light whose faintness causes them to escape ordinary observation. As an aid to man, however, the light from the vegetable kingdom is far less useful than that yielded by the animal kingdom.

When the animal kingdom is reached, numerous examples of light phenomena connected with vital processes are found. The familiar firefly of northern latitudes frequently renders summer nights luminous, while the tropical noctilucidæ yield an actual and valuable illumination which has been utilized as light in several interesting ways by the inhabitants of regions in which the insects are found.

The distinguished traveler Kaempfer described the fireflies of Siam as "settling upon the trees like a fiery cloud," and in Brazil Gardner compares them in brilliancy with "stars that have fallen from the firmament and are floating about without a resting place." Kidder says: "In the mountains of Tijuca I have read the finest print of *Harper's Magazine* by the light of one of these

natural lamps placed under a common glass tumbler, and with distinctness I could tell the hour of the night, and discern the very small figures which marked the seconds of a little Swiss watch. The Indians formerly used them instead of flambeaux in their hunting and fishing excursions, and when traveling in the night they are accustomed to fasten them to their feet and hands. And they are used by señoritas for adorning their tresses. Prescott narrates the terror they inspired in the Spaniards in 1520. 'The air was filled with "cocuyos," a species of large beetle which emits an intense phosphoric light from its body, strong enough to enable one to read by it. These wandering fires, seen in the darkness of the night, were converted by the besieged into an army of matchlocks.' So says Bernal Diaz."<sup>1</sup>

The bearing of the light of the firefly on the light of the future is very important, and the investigations carried on at the Smithsonian Institution a few years ago may introduce a new epoch in illumination. A brief account in the *Philadelphia American* states that, "some interesting experiments upon the nature and origin of the light emitted by the firefly have lately been made by Professor S. P. Langley. From the spectroscope he finds the light to be of exceedingly narrow range of refrangibility. The heat given out is scarcely appreciable, being less than one-half of one percent of that produced by an equal amount of light from a candle or other common illuminant. That the light is a chemical product would seem to be established by the fact that it decreases by products which check combustion (e. g. nitrogen) and increases by products which aid combustion (oxygen), and that the product of the process is apparently carbon dioxide. The subject of the origin of 'phosphorescent' light is one that may develop very interesting features, for, as graphically stated by Prof. Oliver J. Lodge, if the secret of the firefly were known, a boy turning a crank might be able to furnish the energy necessary to light an entire electric circuit. From this standpoint Professor Lodge

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<sup>1</sup> Kidder and Fletcher, *Brazil and the Brazilians*, Phila., 1857, p. 293.

regards as enormous the waste of energy in the machinery of electric light making now in use."

Most of the one hundred and fifty species of animals which are light-producing inhabit the sea where their light is of small importance to man. The wonderful phosphorescence of the tropical seas, which has drawn forth many descriptions of its beauty, is caused by the collective lights of myriads of infusoriæ on the surface of the water.

The day opens up a vast field of activities requiring light for their prosecution. Solar light is normal for the carrying on of these activities, and the night is normal for rest and recuperative processes. The important phenomena of the day are sunrise and sunset; and the day's labor regulates itself to twilight, morning and evening hours, and the hours of broad day divided by the meridian of the sun. Sunrise is attended with certain phenomena, which observant people have noticed.

The Hopi tribe of Arizona, for instance, employ the following terms for sunrise: Sunrise, *talavaiya*; place of sunrise, *tawa yum tyaki*; faintest dawn, *kúyañiptü*; first light, *talti*; light of sunrise, *taldove*; yellow light of sunrise, *sikyañüptü*; before emergence of sun, *tawa küyiva*, "sun appears"; sun-up, *tawa yama*.<sup>1</sup> Few tribes indeed have not been impressed with dawn and sunset, and few in the oblique latitudes have failed to mark the seasonal progress of the sun along the horizon.

There is a wide difference in the amount of sunlight enjoyed by the dwellers on the earth's surface, depending on the height and configuration of the land, its absorbtive and reflective qualities, the presence of forests and vegetation, the amount of moisture and dust in the air, cloud formation, and other elements which suggest themselves to the reader, producing local and periodical variation. To these must be added the seasons and the position in latitude determining the length of the day and the duration of twilight.

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<sup>1</sup> Authority of Dr J. Walter Fewkes.

The superabundance of sunlight has brought about many devices for warding off and tempering the rays and ameliorating their heat. For protecting his eyes from the excessive light man has devised eye-shades, hats, and parasols; and for shade and protection from the heat, shelters of brush, skin, or cloth. In some environments the chief function of the house seems to be for shelter against a burning sun, and this points out a probable origin of the house in tropical countries.

Nowhere is this regulation of daylight more thoroughly carried out than in our modern houses of the temperate regions whose development has been along the praiseworthy lines of more light and air. What the ancients directly accomplished by small light-openings requires now hangings, lace curtains, inside shutters, blinds, perhaps sash curtains, outside shutters, and an awning. These may further be reënforced by shade trees. With all these adjuncts one might be led to believe that the dim light of the early houses is still preferred by the moderns.

As a corollary of protection from the sun follows the observation that tribes living in the shade become lighter in color than their fellows living in the open country. It is also true that there is a characteristic facial modification, such as wrinkling and contorting about the eyes produced in those who are exposed to the glaring light of the deserts or the sea.

Without doubt man is a diurnal animal; his eyes have not the condensing power of those of the *Felidæ* and other nocturnal beasts. The man-apes are also day animals, and those tribes of mankind retaining a degree of primitiveness regulate their rest to the setting and rising of the sun.

With the use of fire begins the history of artificial illumination. The nocturnal light of nature became then of little moment in comparison with fire-lights and the burning brand in the hand of man; the conquest of light over darkness was signalized, and the night side of man's life and his progress toward culture became a theme of surpassing interest.

There perhaps cannot be a satisfactory reconstruction of the period before the knowledge of fire, and the difficulty persists in the subsequent stages of the acquisition and use of fire, and the generation of fire at will—stages grasped by the philosophic mind of Paul Broca.

One fact stands out clearly, that man unacquainted with fire is unknown. With the light of the camp-fire comes the torch, and from this starting point, by the help of observations on less civilized peoples, it may be possible to reconstruct the history of artificial illumination and to check it in some degree by the aid of archeology.

The following table, briefly epitomizing the development of the candle, is presented as the result of extended research in this direction :

#### DEVELOPMENT OF THE CANDLE

##### PROTO-ILLUMINATION IN LINE OF TORCH :

Fireflies used as torches. Fat bodies of birds and fish burned for light.

##### *Proto-torch* (Adventitious and Temporary) :

1. Firebrand, branches, resinous wood, bark, leaves, etc.

##### *Torch* (For Customary Use) :

2. Slivers or other elements tied together in a bundle.
3. Roll of resin wrapped in leaves.

##### *Proto-candle* :

4. Rope soaked in resin.
5. Fiber soaked in fat or wax.
6. Rush soaked in grease.
7. Stick or splint with grease for lighting.

##### *Candle* :

8. Mass of fat formed upon a stick around which is wound a wick of fiber.
9. Candles of wax or fat.
10. Dipped candles.
11. Molded candles ; improved and art candles of 20th century.

While the line of development has proceeded from the rude torch to the candle, the steps marked in the series are suggestive, embracing devices used by different peoples and at divers times. There is not space here to present the results of investigations among different peoples and in special areas. It will be seen that the purpose for which light is to be used, the place in which it is to be used, the period, and the resources of the environment, are among the modifying influences on materials and apparatus. Hence, the complete steps of the development may not be exemplified in a given area, though a number of superposed phases of light utilization may exist side by side. It is true, also, that the growing need for light has brought about a closer association of the means of illumination with the life of man. The smoking torch, for example, is utilized for open-air illumination, while the candle enters the house and companionship of the family.

Following the torch in the line of development comes the lamp, which separated from the stem of the torch at a period when oils and fat came to be used. This may have occurred (1) as a concomitant of migration or after the domestication of animals whose fat was available; (2) at the time of the discovery of mineral oil, (3) or of the utilization of vegetal oils, such as that of the olive and the cocoanut.

The lamp appears to have arisen at a period after migrations into the temperate zones had brought man into new conditions. The principal of these was the longer night, and joined to this was the settlement in comparatively permanent habitations. In this view the firestick and torch were the essential accompaniments of early migration and without doubt determined the spread of man over the earth's surface.

Since the torch, from its perishable character, is rarely found on ancient sites, there is little to be said as to its archeology. The lamp, on the contrary, being a higher idea, involves work in stone, pottery, bronze, or iron, producing objects which survive burial in the soil. Discoveries by French archeologists have



shown that the lamp was in use at the close of the lacustrian bronze age, and up to the present time these are the most ancient objects which have been found that are unmistakably lamps.

It would seem that the lamp with a wick had its origin at a culture plane represented by that of the bronze age, though such employment of fire might have been prefigured by usages in the age of polished stone. Again, the latitude and consequent difference in temperature of stations have exerted controlling influence on the character of the early lamps which it might be possible to employ. Thus climatic conditions render the fuel supply of the lamp solid or fluid and broadly determine the form of the reservoir.

It is almost safe to say that the higher types of illuminating apparatus would not have developed except in the temperate zone or the region of long nights. The tallow candle is a device of cold regions; the same may be affirmed of the open fat lamp. The form of the latter seems to depend upon the character of its fuel supply, and this cause no doubt constantly gives rise to forms of extreme primitiveness in the midst of a high civilization, aside from those descending from the primitive type and retained in use through the working of the large body of survivals of custom in every society.

#### DEVELOPMENT OF THE LAMP

The series might have grouped at the beginning devices for producing a temporary light and those undifferentiated lamps of skulls and bones. The bodies of birds and fish burned by means of a wick also may be classed with the lamps.

#### *Temporary Light*

1. Oil bag from which oil is thrown on a fire to produce a temporary light. Kwakiutl Indians, British Columbia. Lighting apparatus of skulls or bones suggestive of primitive lamps.

2. Lamp. Unworked beach stone with a concavity, supplied with oil and having the wick laid along one edge. Aleut shell heaps.

3. Lamp. Hollowed beach stone with moss wick arranged along one edge. Worked stone lamps. Eskimo.

4. Lamp of pecten shell with oil and wick of rush pith. Ainos, Japan, Fusus shell hanging lamp. Orkney islands.

5. Lamp. Terracotta saucer, China. India, etc.

6. Terracotta saucer with edge pinched up into gutter or gutters for wick. Syria and India.

7. Lamp. Terracotta. Reservoir almost closed over; spout for wick. Lamps of pottery with reservoir closed over. Lamps of bronze with one or more wick-spouts. Roman.

8. Lamps of iron of simple shape with plain open or closed reservoir and with spout, and often having drip catchers and a device for tipping to allow the oil to reach the wick. There is considerable variety of such lamps, which were used in Europe before the epoch-making invention of Argand. Being products of the blacksmith's hammer, they present a certain crudity, as of antiquity. However, there is no reason to doubt that they are the survivals of the forms of the iron age.

It may be interesting to briefly pursue the line of the lamp into the inventive age.

#### *Lamps of the Inventive Era*

9. Lamp of brass with reservoir mounted on rod and stand; several curving spouts. Italian. Development from the Roman lamp.

10. Lamp of brass designed to furnish heavy oil to the wick under hydrostatic pressure. Flemish.

11. Lamp with chimney; draft to flame and heavy oil under gravity pressure. Argand's invention and French inventors.

12. Lamp with chimney and argand burner; heavy oil under forced pressure of a spring. Devices for heating heavy oil. France.

13. Lamp of glass having one or two tubes ; for burning whale oil.

14. Lamp burning "camphene" by means of wick and tubes and without chimney. United States.

15. Lamp with chimney ; ventilated burner ; woven wick raising refined petroleum by capillarity. United States, 1870. Developed burner to end of century.

At present the destiny of illumination is in the hands of the investigator and inventor. Who knows to what heights their efforts will lead ? But before the inventive era, before Argand, if you please, the world satisfied its needs for light with the immemorial simple lamp and smoky torch, increasing the illumination at times by multiplying the number of lights, and casting over scenes of splendor the flare of torches little removed in simplicity from those of prehistoric man.

It may be a wholesome correction of our pride in the advance of a century to reflect that most of the human race is still in the uninventive period, depending for light on torches and simple saucer lamps. The epoch-making invention of the chimney and the discovery of boundless hydro-carbons in the earth have not yet reached the majority of mankind, while the electric light casts its bright rays in a very small area of immense obscurity. Still, there is progress, and gradually tribes, from their beginnings unacquainted with more than the most simple illuminating methods, are seeking more light.

It is interesting to note in this connection the education of the Hopi Indians of Arizona in the use of artificial illumination. The environment of these Indians is semi-arid, and there is such scarcity of fuel in their isolated country that it must be used sparingly for cooking and only as a luxury for illumination. Hence, up to a few years ago all avocations ceased at dark. Four years ago the writer, while encamping at Walpi, noticed only a solitary light at night in the pueblo. There was at that time a demand for candles. Two years later, a number of lights shone

from the windows of the village. Lately coal-oil has become known; a great many families possess the luxury of a coal-oil lamp, and this has worked a great change in the habits of the people.

This seems in epitome the history of illumination.